RADIOLOGY DEVICE COMPRISING IMPROVED IMAGE ENLARGING MEANS

The present invention relates in a general manner to medical radiology devices. More precisely, the invention relates to a device making it possible to obtain high-resolution digital images of organs or of tissues which one wishes to examine (which for the sake of simplicity will be referred to subsequently in this text by the generic term "subject"), as well as of any desired region of the subject.

Radiology devices which implement an X-ray source and a module making it possible to visualize the track of the X-rays having passed through the subject have been known and employed widely for many years. The following overall typology can be established for these devices:

- radiography devices, in which the subject is interposed between an X-ray source and an X-ray sensitive film. This type of device which was historically the first to be used and which is the most widespread, thus provides static images of the subject which must remain immobile during exposure thereof to the X-rays for a time sufficient to obtain an impression of the film by the X-rays. This type of device has rendered great service; it nevertheless has drawbacks, the main ones of which are the following:
  - limitation to the production of static images, thus precluding visualization of the dynamic evolution of the subject in order to characterize certain aspects of its functioning,
  - repeated exposure of radiologists to X-rays and health risk stemming therefrom,
- fluoroscopy devices on the other hand offer access to dynamic images. In these devices, the subject is interposed between an X-ray source and visualization means which in real time convert the

- ✓ direct visualization. In this case, the radiologist directly visualizes the "primary" images which are the first images formed by the visualization means from the X-rays. The visualization means then consist of a converter of the phosphor coating screen type.
- ✓ or indirect visualization. In this case, the device comprises means for acquiring the primary images at the output of a converter (the latter possibly being of the phosphor screen type), via a chain which may include a video camera filming the entire field of an output screen of the converter so as to form a "secondary" image, means for digitizing the image and means for processing, storing and distributing the images to various terminals (which may be on different sites). The document US 4896 344 gives an example of such a device.

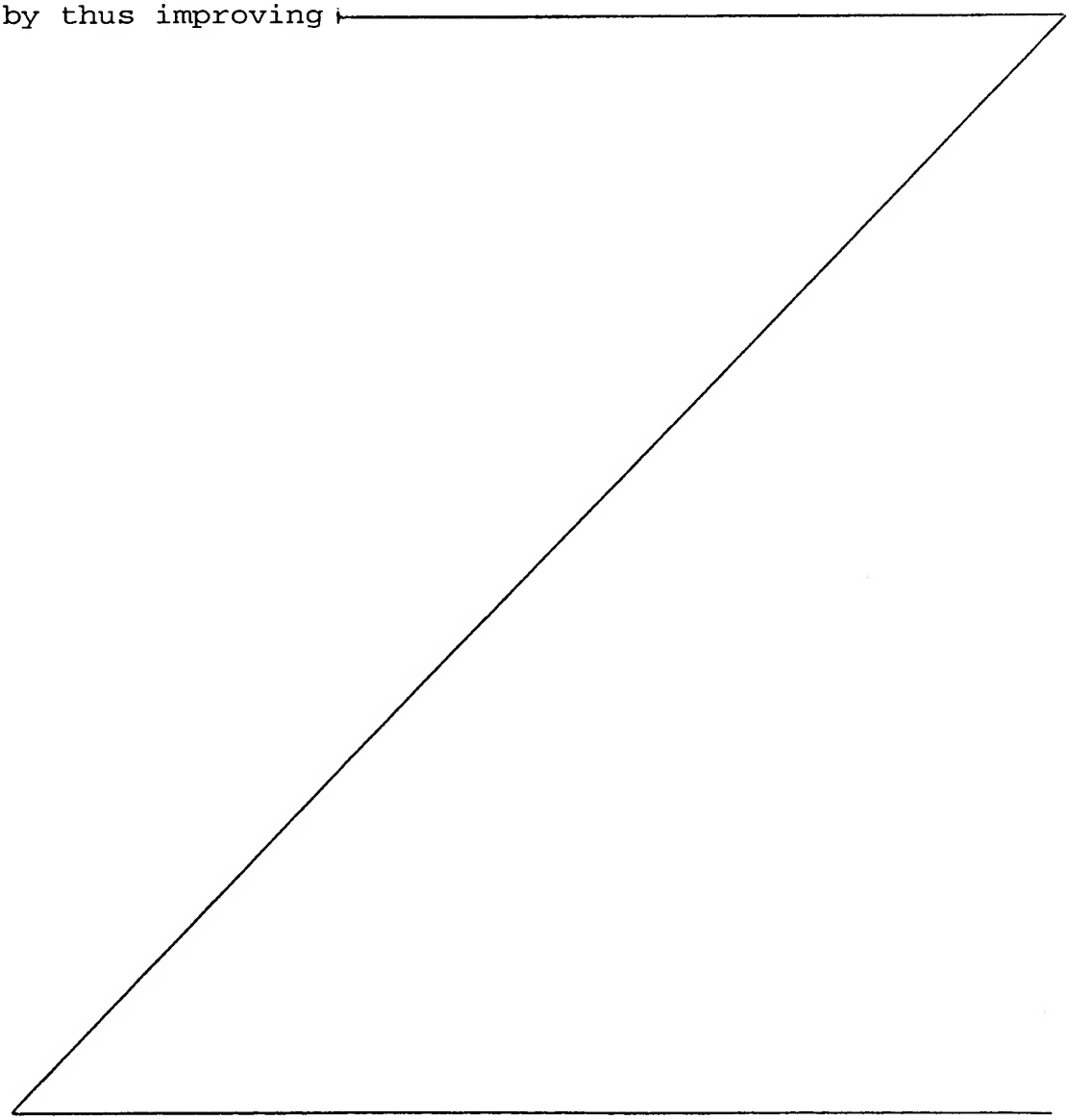
In both cases (direct and indirect visualization), the visualization means allow dynamic viewing of the temporal evolution of the subject (visualization of the functioning of moving organs), thereby constituting an advantage and offering enhanced possibilities of implementation (recording of sequences illustrating the functioning of the subject, live operative assistance, etc.).

These fluoroscopy devices also have drawbacks however, among them being inferior image quality to that of radiography images (especially in terms of contrast), because of the necessary reduction in the intensity of X-ray emission for reasons of safety of the radiologist

(and of the patients), the exposure to the radiation being lengthy.

To attempt to diminish the importance of this problem related to fluoroscopy devices, manufacturers have implemented intensifiers which make it possible to convert the X-radiation into an optical image with high efficiency (that is to say by producing a high number of photons per incident X-ray).

By increasing the intensity of the images produced and by thus improving



will be visualized, given that the secondary images which are enlarged have previously been discretized by the acquisition means: the resolution of the image observed is in this case N times lower than the resolution of the acquisition means, N being the enlargement coefficient.

Moreover, in the case of intensifier devices, the resolution of the primary image is already greatly limited by the resolution of the intensifier itself, which is commonly of the order of from 1 to 2 pairs of lines per millimeter only.

Such a drawback can result in the impossibility of detecting certain details of very small size, such as for example certain early symptoms of cancer of the stomach which are of millimeter size.

Furthermore, the intensifiers of fluoroscopy devices generally comprise curved input screens which produce aberrations in certain parts of the image.

An aim of the invention is to alleviate the drawbacks mentioned hereinabove and to make it possible, on the one hand to construct a radiology device providing high-resolution images of any desired part of a subject, and on the other hand to implement such a device according to an advantageous process.

Another aim of the invention is to make it possible to construct a real-time radiology device in which inter alia the images are almost undeformed.

In order to achieve these aims, the invention proposes, according to a first aspect, a radiology device comprising an X-ray source for exposing a subject to the radiation of said source, means for converting the X-rays into optical images so as to form primary optical images, means for transforming the primary

optical images into secondary optical images, means for digitizing the secondary images and means for displaying the secondary images to a user, characterized in that the means for forming the secondary optical images comprise an optical chain comprising in succession, from the output of the converter to the output of the device, an image enlargement assembly exposed directly to the primary images from said conversion means, an assembly for optical intensification of the enlarged images and a photosensitive matrix sensor for making said secondary images.

Preferred, but nonlimiting aspects of the device according to the invention are the following:

- the enlargement assembly is a variable enlargement assembly, able to enlarge the images according to a desired enlargement coefficient within a given range.
- the enlargement assembly is made up solely of optical elements performing no discretization of the images.
- the device comprises means for moving the elements of the optical chain in a plane generally parallel to the midplane of the conversion means.
- the device comprises a central control unit for controlling the movement of the elements of the optical chain.
- the central control unit is physically distanced from the other elements of the device.
- the device comprises means of monitoring the exposure and the degree of enlargement of the images.
- the assembly for optical intensification of the images comprises components of the MCP type.
- the device comprises means for digitizing the secondary images arising from the photosensitive matrix sensor.

- the device comprises interfaces for distributing the images destined for digital peripherals.
- the device comprises a screen for visualizing the digitized secondary images.
- the means for converting the X-rays into optical images consist of a fluoroscopy screen of the phosphor coating screen type.
- said optical chain is directed along a different axis from the normal to the midplane of the means for converting the X-rays into optical images, the device comprises a mirror for deflecting the primary images to the optical chain and the device comprises a shield for protecting the elements of the optical chain from the X-rays.
- the optical chain comprises a refocusing lens.
- the device comprises a mirror for separating the images arising from the intensification assembly and a digital video camera.
- the optical coupling between the intensification assembly and the sensor is effected by optical fibers.

According to a second aspect, the invention also pertains to the use of one of the embodiments of the device described hereinabove, for real-time radiological examinations (especially for applications in the industrial and maritime sectors).

Other characteristics, aims and advantages of the invention will become more clearly apparent on reading the following description of three embodiments of the invention, given with reference to the appended drawings, in which:

- figures 1 to 3 are representations of the block diagram type of three embodiments of a radiology device according to the invention,
- figure 4 is a schematic representation of image acquisition elements which can be implemented in a radiology device according to the invention.

With reference firstly to Figure 1, there has been schematically represented a first module 10 comprising an X-ray source 11, and a fluorescent screen 12. This module 10 can be a conventional fluoroscopy module, the screen 12 delivering as output from the module 10 a primary visible image corresponding to the track of the X-rays emitted by the source 11 after they have passed through a subject S interposed between the source 11 and the screen 12.

The device also comprises a second module, referenced 20, for acquiring the primary images and for forming secondary images. As will be seen in greater detail subsequently in this text, the spatial coverage of these secondary images can correspond to that of the primary images formed on the fluorescent screen 12, or else to only a part of these primary images.

The module 20 comprises in a lightproof enclosure:

- an optical assembly 22 for variable enlargement of images, which is focused on the fluorescent screen 12,
- an image intensifier assembly 23 for producing, from the images enlarged by the assembly 22, images of greater luminous intensity,
- a refocusing lens 24 for reforming intensified images at the output of the assembly 23,
- an optical sensor 25, on which the lens 24 is focused, for gathering the enlarged and intensified image and for converting it into a discretized analog secondary image. This sensor can be a CCD type matrix for example.

The optical elements 22, 23, 24 and 25 of the module 20, which are assembled in series and thus form an optical chain, are furthermore mounted on a two-axis movement system which is not represented in the figures. This system can move these optical elements in the two directions coplanar to the fluorescent screen

12 so as to bring in particular the enlargement assembly 22 opposite any desired zone of this screen.

The device comprises a third module 30 for processing and distributing the images arising from the module 20. This module 30, which constitutes a central control unit for the device, comprises in the embodiment represented in Figure 1 the following elements which are interlinked:

- a unit 31 comprising electronic means for digitizing analog signals delivered by the sensor 25, and for processing these signals,
- a unit 32 for the local storage of digital images,
- an interface unit 33 for communicating video signals (originating from the sensor 25 and/or destined for external video peripherals),
- an interface unit 34 for communicating digital signals,
- and an exposure and enlargement control unit 36.

The module 30 also comprises means (not represented in the figure) for controlling the system for moving the elements of the optical chain of the module 20, in particular of the enlargement assembly 22.

The device finally comprises an interface 40 for local visualization of images which can consist of a high-resolution video screen hooked up to the units of the module 30. This interface 40 can be a digital screen receiving the secondary images digitized by the unit 31 of the module 30.

This device can function according to a continuous mode, likewise the subject of the invention, described hereinbelow:

The subject having been exposed to the radiations of the source 11 so as to form a dynamic image on the screen 12, the radiologist can visualize in real time on the screen 40 a secondary image corresponding to the

entire primary image formed on the screen 12, covering for example a widened field of the subject inside which the radiologist is searching for specific zones of study.

By virtue of the means of control of the movement system of the module 30 and by virtue of the exposure and enlargement control unit 35, the radiologist can then control the continuous movement of the optical chain formed by the elements 22, 23, 24 and 25 in a plane parallel to the plane of the screen 12, as well as the degree of enlargement of the image formed at the output of the lens 22 and transmitted to the other optical elements of the chain. This degree of enlargement can be fixed by the radiologist at any desired value within a given range, which depends on the choice of the assembly 22.

It will be noted that all or some of the elements of the module 30 may be situated some distance from the other constituents of the device (in particular from the modules 10 and 20), for example in a separate room dedicated to the control of the device and to the visualization of the images, or even in a separate building. In this case, the length of the link between the module 30 and the module 20 (which consists of at least one cable for transmitting the images from the optical sensor 25 to the module 30, and for transmitting the commands arising from the module 30 to the elements of the optical chain of the module 20) is suitably adapted.

To control these movement, exposure and enlargement means, the radiologist is provided with an interface (not represented) which can be associated with the visualization screen 40. This interface can use a control cable, linked to the module 30 to manually activate the image selection and capture process.

The screen 40 can be of any known type, inter alia a liquid crystal screen. The module 30 can also be associated with a PC type control computer supplemented with the commands of the device (commands for exposure, for moving the optical chain and for enlargement, etc.). Such a PC can contain a program for using the device, implementing a menu for the control of the device which is displayed on the screen 40 in combination with the output images from the device.

It is important to note here that according to the invention the resolution of the image is in no way altered by modifying the degree of enlargement, given that the assembly 22 which is composed solely of optical elements does not carry out any discretization of the image.

On the basis of images having a widened field, it is thus possible for the radiologist to identify zones of specific interest, then to move the optical elements and to zoom in on the chosen zone(s), while obtaining at the output of the assembly 22 an image whose resolution is in no way altered.

It will be noted that according to the invention, the chaining together of the snapshots of various zones with various degrees of enlargement is carried out in a continuous manner, this being an advantage in terms of ease of use.

The image (enlarged or otherwise) is transmitted by the assembly 22 to the optical intensifier 23, which will preferably be made up of so-called channel multiplier plate (or MCP according to the acronym in use) elements. An exemplary embodiment of such an element will be found in US patent 3 660 668. It is also possible to link several intensifier elements of the MCP type in series, and thus to obtain an optical gain of the order of 10^3 to 10^7.

By virtue of the optical intensifier 23, the intensity of the radiation of the X-ray source 11 is limit has a level equivalent has that conventionally implemented in intensifier fluoroscopy devices, that is to say the lengthy exposure of the radiologist and of the subject to radiation does not present a health risk.

It will be noted furthermore that an optical intensifier constructed from elements of the MCP type does not include elements of domed geometry such as the input screen of image intensifiers which is conventionally employed the fluoroscopy devices.

This constitutes an advantage insofar as this characteristic does not introduce any distortion of the image. The enlargement assembly 22 is thus the only optical element of the device comprising curved parts, so that the optical aberrations and deformations of certain zones of the image are reduced to the minimum.

The radiologist can thus carry out a continuous examination of various zones of the subject, by moving the optical chain formed by the elements 22, 23, 24 and 25 and by controlling via the unit 35 the enlargement of the image on each desired zone in succession, the enlargement of the image not altering the spatial resolution of the image.

It will be noted that the enlargement of the image is furthermore continuously adjustable by way of the control unit 35, thereby further increasing the flexibility of use of the device according to the invention.

A unit for programming successive movements and enlargements can also be integrated into the module 30 in order to undertake a program of predetermined examinations.

The assembly 22 can also be physically detached from the other elements 23, 24, 25 of the optical chain of the module 20, and it is also possible to control only the moving of this assembly 22 opposite the fluorescent screen 12, image transmission means such as an optical fiber link then being provided between the assembly 22 and the intensifier 23.

It should also be noted that the radiological examination process described hereinabove can be conducted without changing the intensity of the X-radiation to which the subject is exposed. Indeed, since the enlarging of the image does not alter its resolution, it is not necessary to increase the dose of radiation in order to visualize a zone of detail of restricted dimension.

The digital images can be stored by the unit 32 and distributed to any type of digital peripheral (or analog peripheral by virtue of the video signals communication interface unit 33). These peripherals may be visualization screens, high-resolution printers, remote means of storage and archiving, etc. They may be located on the same site as the device described above, or be situated remotely on other sites furnished with a link with the module 30.

By virtue of the device described hereinabove, the radiologist can also take a first fast snapshot of a widened field containing the entire subject, then study the image produced at his/her leisure, the source 11 being inactivated. After having identified the specific zones which he/she wishes to study in greater detail, the radiologist can then reactivate the source 11 to obtain detailed images of these zones with the full resolution of the assembly of sensors 25. This mode of use of the invention makes it possible to further reduce the level of exposure of the radiologist and of

the subject to radiation.

The module 30 can also comprise, in particular in the unit 31, all the known means for digitally processing the image, such as means for manipulating the image (choosing zones, rotation, processing of contrast and thresholding operations, etc.).

It will be noted that the resolution of the images produced by the device according to the invention is very markedly greater than that of the images produced by the fluoroscopy device implementing image intensifiers. The resolution of the images of these devices is in fact limited by the resolution of the intensifiers, which is at best of the order of from 1 to 2 pairs of lines per millimeter; the use of intensifiers of the MCP type, combined with the absence of discretization of the images during their enlargement, makes it possible to achieve a greater resolution.

It will furthermore be noted that by virtue of the means of processing and of distribution of the digital image of the module 30, the device according to the invention offers multiple possibilities of practical utilization. The files of the images may in fact be easily transmitted by electronic means to other sites so as, for example, to solicit the opinions of different experts.

It will also be noted that the use of printers, or of any other type of known peripheral for registering and/or printing on a medium such as paper (conventional or of photographic quality depending on requirements) the digital images arising from the module 30, constitutes an extremely flexible and economical means of obtaining negatives equivalent to radiographic negatives, so that the device according to the invention can be used as a radiography or fluoroscopy

apparatus.

Figure 2 represents a second embodiment of the device according to the invention in which the module 20 is folded at 90°, the image from the fluorescent screen 12 being deflected to the optical chain of the lens 22 by way of a deflecting mirror 26.

In this embodiment, the optical chain of the module 20 is oriented generally parallel to the plane of the screen 12, a 90° deflecting mirror 26 deflecting the images from the screen 12 to the enlargement assembly 22. A "T"-shaped shield 27 is also provided in order to protect the elements of the optical chain from the X-radiation.

Figure 3 presents a third embodiment of the invention in which between the image intensifier and the refocusing lens 24 there has furthermore been interposed a prismatic mirror 28 for separating the image, so as to separate the images transmitted by the optical intensifier into two beams directed respectively towards the sensor 25 and towards a digital video camera 29, these two elements being linked to the unit 31 of the module 30.

This third embodiment allows separate acquisition of dynamic images (by the camera 29) and of static images (by the sensor 25); this arrangement makes it possible to further increase the flexibility and the performance of the device.

Figure 4 represents a variant embodiment of elements of the optical chain of the device according to the invention, in which the image intensifier 23 is linked to the sensor 25 by a network of optical fibers 24' in replacement for the refocusing lens 24.

Of course, the device according to the invention is not

limited to the embodiments described hereinabove, but may be embodied according to any variant within the scope of the person skilled in the art.

The use of such a device is not limited to the medical sector; the device described hereinabove can in fact also be implemented in any other sector of application of radiography apparatuses, and of X-ray examination in general.

In particular, the use of such a device for the inspection or nondestructive qualitative analysis of materials, for example in the industrial sector (inspection of walls or of pipelines, etc.), maritime sector (inspection of ships or of submarines, etc.), etc., makes it possible to access the advantages of real-time flexibility of use described hereinabove with regard to medical examination.